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(19) THE PATENT OFFICE LONDON

(72) Inventors SHELDON S. WILSON and DONALD G. KIMBLE

(54) METHOD OF AND APPARATUS FOR EVALUATING, REGISTERING AND IDENTIFYING GEMSTONES

(71) I, SHELDON SEYMOUR WILSON, a citizen of the United States of America, of 1801 Avenue of the Stars, Los Angeles, California, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention provides methods and apparatus in which a plurality of gemstone measurement terminals are connected to a data processing center, in which each terminal includes transducer means for automatically developing electrical signals representing predetermined gemstone parameters such as carat, cut, color and clarity. The electrical measurement signals thus developed are communicated to the data processing center by transmission means linking each terminal therewith. Segments of the generated data, particularly from the cut or facet measurements, are stored at the data center for use in later identifying the gemstone having a previous record. In this manner, each processed gemstone, particularly cut diamonds, is registered at the data processing center.

Moreover, the measured parameters of carat, cut, color and clarity, representing the four-Cs of the stone, may be compared with ideal measurements of a perfect stone also stored in the form of electrical signals at the data center, so as to arrive at an objective valuation of the gemstone. The present invention provides standardized measurement means at each of the terminals for measuring the angles or orientations of gemstone bezel and pavilion facets. This cut angle information in addition to providing data from which an objective valuation of the stone may be made, also provides identifying or "fingerprinting" data, unique to each stone, for storage in electronic form at the data center.

These and further objects and various advantages of the method and apparatus for evaluating, identifying and registering gemstones according to the present invention will become apparent to those skilled in the art from a consideration of the following detailed description of an exemplary embodiment thereof. Reference will be made to the appended sheets of drawings in which:

Fig. 1 is a block diagram of the overall system method and apparatus for evaluating, identifying and registering gemstones.

Fig. 2 is a fragmentary perspective view of the measurement apparatus at each gemstone identification terminal for developing the electrical signal measurements of processed stones.

Fig. 3 is a plan view of the measurement apparatus of Fig. 2, in which portions of the assembly are broken-away for clarity.

Fig. 4 is a vertical sectional view of the apparatus of Fig. 3 taken generally along IV—IV and showing the pavilion cut and bezel cut sensors cirumferentially disposed about a centered brilliant cut diamond.

Fig. 5 is a further vertical sectional view of the measurement apparatus of Fig. 2 through 4 illustrating a height probe assembly for measuring the height of a diamond gemstone.

Fig. 6 is a fragmentary plan view of the measurement apparatus as seen from VI—VI of Fig. 5 showing a variable iris

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assembly for centering and measuring the girdle diameter of the cut stone

Fig. 7 is a partial enlarged vertical sectional view of the brilliant cut diamond of Fig. 5 cooperating with the height probe.

Fig. 8 is a detail top plan view of the brilliant cut diamond of Fig. 7 as seen from VIII—VIII therein, showing the culet facet of the diamond.

Fig. 9 is a detail bottom plan view as seen from IX—IX of Fig. 7, looking into the table facet of the diamond.

Fig. 10 is a further partial vertical cross-sectional view of the height probe assembly of Fig. 5 although here shown in its retracted condition.

Fig. 11 is a partial vertical sectional view of the measurement apparatus of Fig. 2 showing the components thereof for effecting the bezel angle cut measurement.

Fig. 12 is a fragmentary view of the components of Fig. 11, partly in section, illustrating the light patterns occurring during the bezel angle measurement.

Fig. 13 is a further fragmentary vertical sectional view of measurement apparatus illustrating the arrangement of the components for effecting the pavilion angle measurements.

Fig. 14 is a fragmentary enlarged view, partly in section, of the brilliant cut diamond shown in Fig. 13 and showing the light patterns occurring during the pavilion cut angle measurement.

Fig. 15 is a fragmentary vertical sectional view of the measurement apparatus of Fig. 2 illustrating the arrangement of components for taking the color measurement of the brilliant cut diamond shown centrally of the Figure.

Fig. 16 is an enlarged fragmentary plan view of the bezel angle sensor mask of Fig. 15 as seen from XVI—XVI therein.

Fig. 17 similarly is an enlarged fragmentary plan view of the pavilion angle transducer mask taken from XVII—XVII of Fig. 15.

Fig. 18 is a fragmentary vertical sectional view of measurement apparatus illustrating the arrangement of components functioning during a clarity measurement of the cut gemstone.

Fig. 19 is a diagrammatic perspective view of the scanning pattern associated with the functioning of the clarity measurement components as shown in Fig. 18.

Fig. 20 is a detailed electrical block diagram of the components comprising the terminal computer of each gemstone identification terminal as illustrated in Fig. 1.

Fig. 21 is a detailed block diagram of the portion of the terminal computer providing for automatically measuring the bezel and pavilion facet angles.

Fig. 22 is a further detailed block diagram of the portion of the terminal computer providing for the color measurement of the gemstone.

Fig. 23 is still another detailed block diagram showing the computer terminal circuitry associated with the clarity measurement.

With reference to Fig. 1 the present invention provides method and apparatus for identifying and registering gemstones in which a data processing center 30 is informatively linked, in this instance by a telephonic transmission means 31, to a plurality of remotely located individual gemstone identification terminals, here shown as terminals No. 1, No. 2, No. 3 and No. 4. Although only four such terminals are shown in Fig. 1, the number and location of these devices is generally unlimited. Data processing center 30 may be provided of well-known data processing equipment including computers, memories, input-output devices, recording devices, etc. Each gemstone identification terminal, such as terminals Nos. 1 through 4, may be located at establishments such as jewelry stores, national and international gemstone organization offices, government offices, etc., to provide generally widespread accessibility to potential users of the system.

Each terminal is comprised of means for measuring predetermined gemstone parameters, such as carat weight, cut or facet angles, color and clarity, and for directly developing analog and/or digital signals representing the magnitudes of these measurements. Preferably, the electrical signals will be processed at the individual terminals so as to convert these signals, if not already converted, to a digital format for transmission to the central computer station by the transmission means.

In this manner the data from each gemstone processed at one of terminals Nos. 1 through 4, in the form of electrical digital signals representing weight, cut, color and clarity parameters may be stored in the data processing center 30. As an important aspect of this operation, it is essential that the measurement means for developing these electrical signals be standardized and thus the same at each of the various remote terminals. Such standardization is provided by the present invention such that any given gemstone processed at one of the terminals, will generate the same electrical data or signals when processed at another of the terminals, or when processed at the same terminal at a later time.

This uniformity of measurements at the various remote terminals provides two important advantages. First, the standardization affords an effective basis for

evaluating and placing a value on each processed gemstone. More particularly to achieve this objective valuation, data processing center 30 may include a data bank or data stored in an electronic memory representing the electrical signals which would be generated at the identification terminals by a perfect gemstone. For example, an idealized perfect brilliant cut diamond will exhibit certain cut, color and clarity parameters which may be represented in electrical form in a memory associated with data center 30. This electronic data so stored may be compared with the corresponding electrical data signals generated and transmitted to the center by terminals Nos. 1 through 4 via telephonic transmission 31 There will of course be deviations between the idealized data and the electrical signals developed in response to the various brilliant cut diamonds measured by the individual terminal stations. Such deviations provide the objective or standardized basis for assessing and placing a value on the stone.

Secondly, the generated electrical measurements constitute "fingerprint" data uniquely identifying each gemstone which is surveyed at one of the terminals. Indeed, so much data representing the gemstone parameters may be developed at the measurement terminal that only certain segments of such data is necessary for identification of the stone.

Although the present invention may be adapted to process many differently cut gemstones, such as: marquise, pearshape, oval and emerald cut, the embodiment of the invention disclosed herein provides for processing brilliant or round cut diamond stones as these are the most popular of the precious gemstones. For identification purposes, the weight in carats and the color and clarity of such brilliant cut diamonds may be used, however it has been found that measurements of the cut or facets of the stone provide a far superior means of identifying each diamond. In particular and as disclosed more fully hereinafter, the angular orientation of the bezel cuts and pavilion cuts afford unique "fingerprints" of the stone where angle measurement data may be stored in data processing center 30 for use in subsequent identification of the same stone. As the great majority of diamonds are hand cut, each stone is unique in the angular orientation of the facet planes. So unique is the cut of each diamond, that even the most carefully and closely matched pair of diamonds can be individually identified under the discriminating "eye" of the cut measurement means provided at each of the terminals.

Moreover, the unique "fingerprint" data developed at the remote terminals provides a means for registering each gemstone, in this instance each brilliant cut diamond, by transmitting such "fingerprint" data to the data processing center 30 together with a registration number and/or the name of the stone's owner and address. In this manner any brilliant cut diamond may be registered at center 30. Data processing center 30 may be a sub-center linked to an international data center or center 30 may itself be the international data bank or registry linking identification terminals stationed all over the world. In addition to the owner's name and registration number, other data may be associated with the stone such as the name of the party or company which sold the stone, a list of previous owners, the name of the insurer, if any, etc.

Each gemstone identification terminal comprises a terminal computer 32, a weighing station 33 for generating a carat weight signal, and a measurement station 34 for generating signals representing cut, color and clarity of the stone. In addition, a printer, a typewriter and a CRT display 36, 37 and 38 respectively may be provided to assist the operator in communicating with the terminal computer 32 and with data processing center 30. In a manner well known to those familiar with the computer art, typerwriter 37 may be employed to enter data into terminal computer 32 and from there into data processing center 30 and also for the purpose of initiating a measurement sequence of a processed gemstone. CRT display 38 acts as a director, displaying entered data and in general assisting the man-machine interface. Printer 36 may be multi-position line printer for generating a printed record of the transaction.

Although terminal computer 32 and data processing center 30 may be programmed in many different ways to provide a variety of interrelated functions, the following sequence of events represents a typical transaction. The diamond gemstone may be presented by its owner to an authorized jeweler having a terminal installation either at his store or at a local terminal center. The jeweler operates one of the function keys of typewriter 37 to establish an "on-line" condition in which data processing center 30 is automatically dialed so as to link the terminal computer 32 with the data center through telephonic transmission 31. When this communication has been established, the jeweler will enter on typewriter 37 a code which specifically identifies him to the center 30. He then enters a transaction code, for example code 1 to indicate that a gemstone is being presented for original identification and registration. He then enters via the typewriter keyboard the

owner's name and address, the insurance company, and the purchase history as is available. The diamond is thereupon placed upon the weighing station 33 where it is weighed and an electrical signal representing a weight parameter, such as carat weight, of the gemstone is automatically generated and fed to computer 32. From weighing station 33 the diamond is removed and placed on a rotatable observation platform 39 of measurement station 34 as shown in Fig. 2. Apparatus 34 is thereupon activated by entering a code at typewriter 37 and the stone's cut, color and clarity are automatically measured as more fully described hereinafter with the resulting electrical signals representing these parameters being fed to and for processing by terminal computer 32. The cut, color and clarity measurements may include as disclosed herein, a height measurement and a girdle or girth diameter measurement, the values for these parameters being represented again as electrical signals which are entered into terminal computer 32.

Having completed the survey or measurement sequence associated with station 34, the electrical information in terminal computer 32 is converted to a digital format if not already in digital form and is prepared for telephonic transmission to center 30. The preliminary processing of these data signals by terminal computer 32 is described herein in greater detail in connection with Figs. 20 through 23.

If indeed the gemstone has never before been registered, then data processing center 30 may issue a registration number which is transmitted to terminal computer 32 for printout by printer 36 and/or display by CRT display 38. On the other hand, data processing center 30 may have a program which is automatically activated for comparing the identifying signal parameters from the supposedly originally registered stone with previously registered "fingerprint" data. If a match is detected, that information may be presented to a supervisor at data processing center 30 who may then follow a prescribed course of action calculated to (1) recover the gemstone if stolen and (2) protect all parties concerned from false arrest and other legal complications. Briefly, such a system might include a rapid computer check against a list of lost or stolen gems.

Unique code numbers may also be established for other transactions. For example, a code number 2 may be used for identifying a previously registered diamond. In such case, the gemstone parameters or "fingerprint" are compared at data processing center 30 with the previous registered data from the allegedly same stone and if a match is achieved, then center 30 may signal that information to the terminal station. A code number 3 may provide for registering a change of ownership. A code 4 may be for a change of insurer. Code 5 may be for amending purchase information which may include the selling price or information concerning a new mounting. A still further unique code number may provide for searching an unknown stone presented at a identification terminal with the entire data bank of prior registration at center 30 or with a list of lost and stolen stones. If the stone has been previously registered, that information will be relayed to the terminal and a complete printout of the registration and history of such stone may follow.

Gemstone Parameters

To assist in understanding the construction and operation of measurement station 34 and terminal computer 32 it is helpful to consider the various characteristics of a round or brilliant cut diamond. In general, the parameters involve the four Cs of a diamond, namely carat, cut, color and clarity.

The carat is the weight parameter, wherein one carat equals two hundred milligrams or one hundred points. The weight of the diamond developed by weighing station 33 may be measured to better then plus or minus .5 points which is equivalent plus or minus 1 milligram. Although many stones will weigh the same, this nevertheless could be used as one broad identifying parameter of a processed stone. Of course, the weight influences the value of the diamond such that the measured weight of any processed diamond can be correlated to a value factor which will contribute to the overall stone worth.

Although station 34 may be adapted within the scope of the invention to measure a variety of stone cuts, such as marquise, emerald, pear and oval shape, and other fancy cuts, the presently disclosed embodiment more fully described herein provides for surveying brilliant (round) cut stones. A brilliant cut stone 41 is shown in Figs. 8 and 9 in which the primary cuts, those of most importance in producing the diamond's brilliance, are the table facet 42, eight bezel facets 51 to 58, also referred to as crown facets, and eight pavilion facets 61 to 68. For perfectly cut diamond, one which will provide the greatest brilliance or sparkle, bezel facets 51—58 will have their planes cut at an angle of 34.5 degrees from the plane of the table facet 42 and will be symmetrically and equally spaced at 45 degree positions about the circumference of the stone. Also for the perfect stone pavilion

facets 61 to 68 will exhibit a 41 degree angle relative to the table facet plane and will also be symmetrically spaced 45 degrees apart about the stone axis. A perfectly cut stone will also exhibit ideal proportions related to the diameter of the girth or girdle 71, as shown in Fig. 7 in which the overall height of the stone 41 is composed of a 43.1 percent of the girdle diameter between girdle 71 and a culet facet 72, 1/2 percent of the girdle diameter for the width of the edge of girdle 71, and 16.2 percent of the girdle diameter between the table facet 42 and the edge of girdle 71. Thus the overall height of the stone as the term is used herein is measured between the table facet 42 and the culet facet 72. Also as shown in Fig. 7, the breadth of the table facet 42 for a perfect stone should equal 53 percent of the girdle diameter. These proportions of the stone are for a diamond which has been proven to provide the greatest fire or scintillation which is due to internal refraction and reflection of light entering the stone. It should be observed that an internal ray of light striking a facet of a diamond within the critical angle of 24 1/2 degree from the perpendicular, will be partially internally reflected and partially transmitted. If the angle is greater than 24 1/2 degrees the ray will completely internally reflect.

The remaining facets of the gemstone 41 may be considered grace cuts which although improving the brilliance of the stone are not as critical as the foregoing cuts mentioned. These grace cuts consist of upper girdle facets 73, star facets 74 and lower girdle facets 76.

The foregoing reference to the orientation of the bezel and pavilion facets refers to an ideally cut stone. For most if not all stones these facets will deviate from the ideal, and it is such deviation which provides the individualized characteristics permitting identification of each brilliant cut diamond in accordance with the present invention. In fact, there is less than one chance in 50 billion that any two stones could match. The marquise, emerald, pear-shape and oval cuts also have bezel and pavilion facets, the deviation of which from the ideal cut may be measured in accordance with the present invention.

The color of a stone, in particular a diamond, is defined in the United States by Federal Trade Commission regulations, and by regulation and trade custom elsewhere in terms of the degree of yellowness. This yellowness is caused by the presence of nitrogen, impurities in the diamond host. The ideal gem or perfect stone is colorless. The least valuable diamond has a strong yellow tinge and is known as a Cape. To accurately determine the degree of yellowness, various methods are used, all of which have some uncertainty. One method involves using a set of color graded stones which jewelers may match with the stone in question to arrive at a color and thus grade comparison.

The clarity of a stone refers to the imperfections, more properly known as inclusions, which are present in most gemstones. In the trade, various methods are used to describe the number of inclusions in a stone, generally in very broad and unprecise terms, such as "perfect", "very slightly imperfect", etc. In the United States all rating methods are based on a Federal Trade Commission ruling which states: A perfect diamond has no inclusions visible to the trained observer when the stone is viewed under a 10 power microscope".

For the present invention, means are employed to reduce these various gemstone parameters to precisely defined electrical signals which are generated directly from transducers measuring the stone's characteristics. There is no subjectiveness in the measurements performed.

Terminal Components

As discussed above, each terminal is comprised of a terminal computer 32 which is more fully described in connection with Figs. 20 through 23. Computer 32 among other things serves to receive the various measurement signals from weighing station 33 and measurement station 34 and to convert such signal information to a form suitable for telephonic transmission, such as by means of modems. Weighing station 33 may be provided by a commercially available scale or Balance (not shown) from which an electrical digital signal or as in this instance analog signal representing the weight parameter in carats and points is developed for feeding into terminal computer 32. Following the weighing operation at station 33, the stone is removed therefrom and placed on an observation platform 39 of measurement station 34 as shown in Fig. 2.

The apparatus of measurement station 34 in general comprises means for centering the stone, in this instance a brilliant cut stone of the type shown in Figs. 8 and 9 as stone 41, wherein such means here is provided by an electrically driven variable iris assembly 81 as best shown in Figs. 4 through 6. The brilliant cut gemstone is placed on platform 39 with its table facet down and resting on the upper platform surface as shown in Fig. 4. Assembly 81 serves to align the axis of the stone with an axis of platform 39 which is rotatable.

The apparatus of station 34 further comprises drive means for rotating the gemstone, here in the form of a synchronous

motor and gear drive assembly shown generally at 82 of Fig. 2 and mounted on a stand 85. Assembly 82 rotates platform 39 through a gear coupling 88 as best shown in Fig. 2.

Considering further the general elements comprising station 34, during the measurement of the stone or diamond cuts, light source means are provided for directing light at the rotating gemstone causing such light to be dispersed or deflected thereby. Such light source means are here provided in the form of laser light source 83 shown in Figs. 11, 15 and 18, which is operative during measurements of the bezel facet and color parameter and thus serves as a bezel light source means and a color light source means although in practice the same source 83 is employed. Station 34 further includes a pavilion cut light source means, here in the form of laser source 84 best shown in Fig. 13, which functions during the measurement of the stone's pavilion facets. In addition to laser source 83 when functioning as a color light source means, a second color light source means in the form of laser source 86 as shown in Fig. 15 is provided. As discussed more fully herein, sources 83 and 86 have different wavelengths such that the two sources together serve as a comparative light source means for measuring the diamond's color. Also included within this group of light source means is still another light source, a clarity light source 87 shown in Fig. 18, arranged to direct light into the stone and cause therein either absorbtion or scattering of the light by internal stone flaws. Thus source 87 is employed to provide a measurement of the stone's clarity.

Station 34 also generally comprises photo-electric sensor means arranged relative to the rotating gemstone on platform 39 so as to selectively receive light dispersed by the stone pursuant to reflection, refraction, etc., from light originating from the various light source means discussed above. Generally stated, these sensor means issue electrical signal information representing predetermined gemstone parameters such as the accuracy and peculiarities of the gemstone cut, the color of the stone, its clarity, and the existence of flaws or inclusions. Here, the photo-sensor means are provided by a bezel sensor assembly 91 as best shown in Figs. 2, 3, 4, 11 and 16, serving as bezel sensor means arranged in light receiving relation with respect to light emanating from the bezel facets as more fully disclosed below. Similarly, a pavilion sensor assembly 92 as shown in Fig. 2, 3, 4, 13 and 17 is arranged in light receiving relation with respect to light reflected off the pavilion facets so as to provide a measure of the pavilion cut angles. For the color measurement, a comparative sensor assembly 93 is employed, mounted as shown in Figs. 10 and 15 at the end of a height probe assembly 94 for selectively responding to the different frequencies of light from the comparative light source means provided as above mentioned in the form of laser sources 83 and 86. Finally, a clarity light sensor assembly 96 also shown in Fig. 15 serves to provide means for detecting light scattered or absorbed by internal stone inclusions or flaws from light originating from source 87.

The particular construction and operation of measurement station 34 disclosed here may now be described in relation to the sequence of measurement steps performed on a brilliant cut stone, especially a diamond, as follows.

Girdle Diameter and Height Measurements

After the stone has been weighed at station 33 and has been placed on platform 39 with the table facet resting thereon, station 34 is activated by applying a start signal to a control logic circuit 101 as shown in Fig. 20, where such start signal may be generated by punching a key on typerwriter 37. Circuit 101 in turn initiates a timing sequence provided by fixed timer 102 which causes an iris drive signal to issue over connecting line 103 to and for commanding variable iris assembly 81 to close on the stone. This will serve to center the stone at the axis of rotation of platform 39 as shown in Fig. 6. For this purpose, assembly 81 includes a variable iris 104, a set of spring biased fingers 106 which are forced inwardly by the iris so as to engage the stones girdle and force the stone to a center position, and an electrically operated drive 107, which may be provided by a motor or solenoid 107 and which receives the drive signal over a line 103 as shown in Fig. 3. Such signal causes closing of the iris by means of linkage 108 connecting the variable mechanism of iris 104 to drive 107. Linkage 108 may have a slip clutch feature such that closure of the iris is limited upon fingers 106 abutting the stone girdle. Cooperatively connected with drive 107 in a manner well known in the art, is a position sensor 109 serving to issue an electrical position signal over connecting line 111 representing the diameter of the stone's girdle. Sensor 109 may be provided by a linear potentiometer.

Thus assembly 81 not only provides for centering the stone, but also provides over connecting line 111 a girdle diameter signal GD, which assists in the identification of the stone and in assessing the proper dimensions for the remaining measurements of the stone's cut. The GD signal on line 111

is in analog form and is fed to the terminal computer 32 as shown in Fig. 20 for storage therein.

During the time that iris 104 is still closed on the stone, a height measurement is performed. This is effected by timer 102 issuing over a connecting line 112, a height probe control signal which as shown in Fig. 5 is sent to a height probe drive 113 of height probe assembly 94 causing a height probe 114 to be driven downwardly such that the axial end 116 thereof abuts the culet facet of the stone as illustrated in Figs. 5 and 7. A height position sensor 117 cooperatively connected with drive 113 in the manner of sensor 109 and drive 107 causes an electrical analog signal Ht to issue over a connecting line 118 to terminal computer 32 of Fig. 20 representing the stones height between the table and culet facets. The height measurement signal Ht is employed in conjunction with a color measurement signal to arrive at a per unit color value signal as discussed more fully herein. Additionally, the height signal may be compared with the girdle diameter signal to assess the ratio therebetween, where a perfectly cut stone will have the proportions previously discussed and as shown in Figs. 7, 8 and 9.

At this point fixed timer 102 of terminal computer 32 issues a signal over line 103 causing iris assembly 81 to retract while probe 114 is still engaged with the stone culet. The height probe thus holds the stone in place while fingers 106 are withdrawn. Thereupon timer 102 issues a signal over line 112 causing the height probe assembly 94 to retract. Its retracted position is shown in Fig. 10. An enlargement of its extended position abutting culet facet 72 by axial end 116 is best shown in Fig. 7. Upon retraction of the height probe, the stone is left in free-standing position centered on observation platform 39.

Bezel Angle Measurement and Index Search

The measurements of the bezel facets, pavilion facets, the color measurement and clarity measurements are all performed during a rotation mode of the stone. This rotation mode is initiated following the retraction of the height probe by fixed timer 102 which issues a control signal to the motor drive assembly 82 over a connection line 119. This sets the stone into rotation. To provide for correlating the functions of the bezel, pavilion, color and clarity measurements with the rotational position of the stone, terminal computer 32 includes a rotation sector counter circuit 121 and a sequence select counter 122 which are generally shown in Fig. 20 and more completely shown in Fig. 21, for deriving sequence timing information from the AC motor current associated with the synchronous motor of motor drive 82. In general, counter circuit 121 and counter 122 serve to divide the frequency of the AC motor current into units suitable for controlling the various measurement functions as the stone is rotated by platform 39 in response to the synchronous drive. In this manner circuit means informatively connect the means driving platform 39 and thus the drive means rotating the stone with the bezel, pavilion, color and clarity sensor means such that the signals issued thereby may be correlated to the angular position of platform 39 and thus of the gemstone.

Generally stated the bezel angle measurement or survey is performed by sensing the angular pattern of light images emanating from each of the bezel facets, wherein these images are representative of the cut angle or orientation of the associated facets. For this purpose, with the gemstone rotating on platform 39, a beam of light or other suitable radiation is generated by bezel laser source 83 from beneath platform 39 as best shown in Fig. 11 so as to impinge at a central point of the table facet 42 of the stone. Platform 39 is transmissive to the light or radiation generated by source 83 and is in this instance by a pair of glass plates 126 and 127 between which is sandwiched a reflective or mirrored surface 128. This is best shown in Fig. 12 as a beam 129 of radiation from source 83 generally focused at the table facet of the stone such that beam 129 passes upwardly through plates 126 and 127 and surface 128 emerging into the stone as shown.

It has been found that a brilliant cut stone, and particularly a diamond, will refract and reflect such a source of light generally perpendicularly outwardly from each of the 8 bezel facets such that a light deflection pattern 131 results as shown in Figs. 11 and 12. This pattern shows the light emanating from a bezel facet and being reflected by surface 128 so as to bounce upwardly and impinge upon bezel sensor assembly 91 arranged in light receiving relationship therewith. Such a bezel image 132 is shown in Fig. 16 impinging on the face of assembly 91.

For a perfectly cut stone, each of the bezel facets will exhibit an angle of 34.5° as shown in Fig. 12 sloping away from the plane of the table facet 42, in this instance corresponding to the horizontal plane. Such a perfect cut will in turn be reflected in the image 132 impinging on assembly 91, where any deviation from the predicted point of impingement of image 132 will represent an imperfection in the stone and also an identifying "fingerprint" thereof. As

mentioned above gemstones are primarily hand cut, thus for a typical stone each of the 8 bezel facets will exhibit an angular orintation slightly different from the others. It is this variation in the bezel cuts, and similar variations in the pavilion cuts which enables the apparatus to measure identifying characteristics of the stone and also develop signals representing the degree of perfection or lack of perfection in its cut.

In the disclosed embodiment of the invention the bezel cut deviations are employed to locate an index facet which for this embodiment is defined as the bezel facet exhibiting the greatest or largest angle from the plane of the table facet. Such a bezel facet will display an image, such as image 132, which will be located the greatest distance away from the stone's centerline, or as viewed in Fig. 16, an image closest to edge 136 and furthest from edge 137 of assembly 91. It will be appreciated that a different stone index may be used, such as a bezel facet having the least angle from the table plane, or one of another group of cuts may be used such as one of the pavilion facets or a combination of two or more facet angles.

To locate such an index image, and to provide a sensor capable of measuring the angular orientation of each of the bezel facets, assembly 91 is comprised of an umbrella-like mask 138 which forms a segment of a cone coaxial with the center line of the stone and wrapping approximately 162° about and generally above the stone as best shown in Figs. 2, 3 and 4. The upper portion of the semi-cone shaped mask 138 is truncated to define edge 137. Placed along symmetrically arranged radial segments of mask 138 are a plurality of apertures or windows 139, with the windows of each radial segment being associated with a plurality of photoelectric sensors 141, one for each window (not shown in detail). Referring to the radial column or group of windows 139 and the associated sensors 141 adjacent edge 142 of mask 138 as the first (#1) sector bezel sensors it will be observed from Fig. 3 that there are provided a set of 10 bezel sensor sectors in assembly 91, with such sectors being angularly displaced by approximately 18° so that the 10 sectors are equally spaced about 180° or 1/2 of the stone's parameter. Furthermore it will be observed that a signal will be issued for each window of the windows 139 which receives light from the bezel images, such as image 132. The surface of mask 138 confronting the diamond is disposed such that the distance between the centerpoint on each bezel facet to the surface of the mask is constant for any ideally cut stone. This allows the assembly 91 to assume a fixed position in which it can sense the bezel angles for all sizes of stones within a predetermined size range. This constant distance is achieved by sloping the inside surface of the conical shaped mask 138 at an angle of approximately 12° from the plane of the table facet or in this instance the horizontal plane. Accordingly mask 138 slopes upwardly relative to the horizontal from the outer circumferential edge 136 to the inward truncated circumferential edge 137.

Starting with inward circumferential edge 137 of mask 138 as shown in Fig. 16, windows 139 are radially spaced within each sector by an amount which may be correlated to the angular orientation of each of the bezel facets, here equaling 5° difference in the bezel angles. Similarly, there is an outward radial displacement of the set of windows 139 of each sector relative to the preceding sector, which also may be correlated to the bezel facet angle here being 1/2° of the bezel angles. Thus the second sector of windows 139 are as a unit radially outwardly displaced from the first sector of windows adjacent edge 142 as shown in Fig. 16. The tenth sector, not shown in Fig. 16 but shown in Fig. 3 adjacent an edge 143 carries windows having the greatest radial displacement as a group. The entire array of ten sectors, each with their differentially displaced windows 139 provides a means for precisely measuring the angular inclination of each of the bezel facets, and a means as will be described immediately below for determining an index facet in the first instance.

In general, the index facet is found by rotating the stone such that each of the 8 facets thereof generate images which scan across the face of mask 138. The image and associated facet which activates a sensor window closest to outward radial edge 136 is detected and identified during this rotating sequence. More particularly, numbering the individual windows for each sector as sensors #1 through #12, with the number #1 sensor being located adjacent inward radial edge 137 and the number #12 sensor being located adjacent edge 136, the index facet as defined herein will trigger the highest numbered sensor in the highest order sector of assembly 91.

This may be automatically achieved by a bezel and pavilion angle processor 151 in conjunction with sector counter 122 and sequence select counter 122 of terminal computer 32 as shown in Fig. 20. More particularly counter 121, counter 122 and processor 151 are shown in greater detail in Fig. 21 in which the upper left hand portion of the drawing illustrates diagrammatically

The index facet search is initiated by fixed timer 102 applying an enable signal to a AC-derived clock generator 152 receiving an AC signal from the synchronous motor current so as to synchronize the output clock signal from generator 152 with the rotation of platform 39 and thus with the rotation of the stone. The output of generator 152 in this instance develops a signal consisting of 90 clock pulses per bezel sector of platform 39 rotation. A divider 153 divides the 90 clocks per bezel sector rate by 45 such that a half sector clock generator 154 may generate a clock signal for every half bezel sector of stone rotation. The output of generator 154 in turn is fed to a half sector counter 156 which counts the 40 half bezel sectors of rotation. The upper left hand portion of Fig. 21 illustrates the division of the sensor assemblies into 20 equal bezel sectors centered around the axis of stone rotation. The output of counter 156 is communicated through a gate 157 to a sector counter 158 which advances 1 count for every 2 counts of half sector counter 156 so as to provide a full sector count. The output of sector counter 158 is connected to a sector decode circuit 159 which provides a set of 10 output signals, representing the sector position of platform rotation corresponding to the first 10 sectors S1 through S10 associated with the bezel sensor assembly 91.

Timing information from half sector counter 156 and sector decode circuit 159 is connected to sequence select counter 122 which serves as a means for programming the timing sequence of the index facet search, the bezel angle measurements, the pavilion angle measurements, the color measurement and clarity measurement. The outputs from counter 122 are shown as an INS mode representing the index search mode, an IR mode for an index revolution, a BZ mode representing the bezel measurement mode, a PV mode representing the pavilion measurement mode, a CO mode representing the color measurement sequence and a CL mode representing the clarity measurement mode.

The first output of the sequence from counter 122 provides for initiating the index search mode. Thus a signal is generated at the INS mode output and extended to an sector select circuit 161 which causes circuit 161 to enable outputs from the sensors associated with the bezel sector number #1 windows of assembly 91. The INS mode signal may also actuate the bezel light source 83. Each of the outputs from the 12 sensors associated with each sector, including sector number #1 are extended to a digital scan photo-sensor select network 162. Network 162 is operated by a strobe clock and provides a 4-bit output sequentially enabling one of 12 photo-sensors to be connected through network 161, depending on the sector selected thereby, to level discriminator 164, so as to rapidly scan the outputs from each of the 12 sensors associated with the selected sector.

Accordingly, with sector 1 sensors selected by circuit 161, network 162 functions to scan or read each of the sector 1 outputs individually but at such a rapid rate that the outputs are read several times during a minute rotation of the platform 39. The scanned sensor outputs are fed from network 161 to level discriminator 164 which serves to discriminate against unwanted sensor outputs, such as those attributed to the less brilliant images from the minor facets, such as the star and upper girdle facets.

During the search for the index facet, digital information from the 12 photocells of sector 1 is fed to a series of logic gates and registers for the purpose of ascertaining and memorizing the highest order photocell receiving bezel image light in sector 1 for slightly more than 360° rotation of the stone. This operation is successively repeated for each of the remaining sectors 2 through 10, with the photocells of each such sector being scanned for an interval of slightly more than 360° of stone rotation. At the end of this sequence the circuitry will have stored information identifying the photocell number 1 through 12, and sector number 1 through 10, receiving light image from the bezel facet exhibiting the greatest angle or inclination from the table plane.

For this purpose, the output of level discriminator 164 is connected to a strobed gate 166 the output of which is connected to one of the inputs of a pair of gates 167 and 168 as shown. The output from discriminator 164 is a discrete go/no-go output signal so that an output from gate 166 occurs at the strobed clock time only if the discriminator output is at the level indicating that the photocell scanned at that instance has received bezel image light of a proper threshold magnitude. Along with the output signal information from each of the photocells, network 162 generates a four bit digital signal over connection 169 identifying the photocell number, 1 through 12, being scanned or read at any given instance. This four bit cell position signal is jointly fed to the A and A' inputs of a pair of comparators 171 and 172 and to a pair of transfer gates 173 and 174. Gates 173 and 174 serve to dump the four bit photocell identifying position signal carried by connection 169 into registers 176 and 177 any time that gates 173 and 174 are strobed by the outputs of gates 167 and 168 respectively. The four bit signal carried by

each of registers 176 and 177 is individually connected to the B and B' inputs of comparators 171 and 172 as shown. Comparator 171 serves to compare the B' cell position signal carried within register 176 with the continuously changing four bit cell information at A' from network 162. Similarly comparator 172 compares the four bit photocell information contents of register 177 at B with the instantaneous output of network 162 at A.

For the bezel angle measurement described below, both of comparators 171 and 172 are active. However for the present index search mode, only comparator 172 is employed.

Comparator 172 has a pair of outputs identified as A B and A=B. The A B output is connected the remaining input of gate 168, such that whenever comparator 172 senses that register 177 has stored therein a photocell of a lower number or order than the four bit photocell identifying signal carried by connection 169, then an output signal is issued to the A B input of gate 168. This causes an output signal from gate 106, representing an activated photocell, to pass through gate 168 and thereby strobe transfer gates 174 loading register 177 with a new four bit signal representing the higher order photocell activated by a bezel image. Simultaneously, the output of gate of 168 is extended to and for strobing transfer gates 178, previously enabled by an index search (INS) mode signal from sequence select counter 122, causing the instantaneous count stored on sector counter 158 to be dumped into a sector storage 179. This provides for memorizing the sector in which the output from the highest order photocell was detected.

It will thus be observed, that after a full 360° plus rotation, that register 177 and storage 179 will have memorized the photocell number and sector receiving light from the most inclined bezel facet. This process is repeated for each of the remaining 9 bezel sensor sectors, such that each time register 177 is found to contain a lower ordered photocell than the four bit photocell identifying signal on connection 169 when accompanied by an output from discriminator 164 and gate 166, then the new four bit photocell identifying word or signal will be dumped into register 177. For each of the bezel sectors 1 through 10, 1 1/8th revolution of the stone is required.

Having completed the necessary revolutions for each of the 10 bezel sectors, sequence select counter 122 initiates an index revolution (IR) in which the following operations occur. An IR mode signal generated by counter 122 is applied to transfer gates 180 thereby dumping the sector count stored in sector storage 179 into sector counter 158. Simultaneously the IR signal is applied to and for switching an index found flip-flop 181, driving the flip-flop from a state in which a zero table (ZT) output is a high to a low logic condition. This causes the ZT input to gate 157 to inhibit clock signals from half sector counter 156 from being applied to sector counter 158 and thereby freezing sector counter 158 with the sector location count received from transfer gate 180 which count correspond to the bezel sector in which the bezel image having the greatest deviation occurred. Thereafter, platform 39 continues to rotate and each of the bezel images is compared with the previously ascertained count associated with the most inclined facet, which becomes the index facet.

Comparator 172 has an A=B output for detecting a match between the output of network 162 when accompanied by an output from discriminator 164, with the highest or greatest order four bit signal stored in register 177. At some point in the succeeding full revolution of the platform and stone, such a match will be located. When the match occurs, comparator 172 causes a signal to be issued at its A=B output to flip-flop 181 causing the flip-flop to return to its condition in which the ZT output is high. This change in the ZT signal re-establishes the count connection between counter 156 and sector counter 158 allowing sector counter 158 to advance from the sector count corresponding to the orientation of the stone in which a match at the F=B output of comparator 172 has been obtained. In addition, index flip-flop 181 causes the ZT signal to be applied to half sector clock generator 154 resetting the generator to one of its two states so as to represent the rotational position of the index bezel at a midpoint of one of sectors 1 through 10. Sector counter 158 now proceeds to a count of 20 at which time an index found (IF) signal is issued by sector counter 158, corresponding to the count of 20. At the count of 20 the index bezel facet is centered or faces the leading edge of the first sector and at this time the IF output is connected to divider 153 resetting the divider such that succeeding sector counting can proceed anew. This completes the index search.

Having identified an index facet, it is now possible to measure the particular angles of each of the bezel facets, which are referenced to this index facet, and for measuring each of the pavilion facets as described hereinafter. Also it will be observed that having identified one of the facets as the index facet it is now possible to remove the stone from the platform, subsequently return it to the platform and

repeat the index search above described and thereby locate the same index facet. Thus each stone has its own index facet which will be the same independent of the terminal at which it is processed so as to provide a fixed reference point for that particular stone.

For the bezel facet or angle measurements, both comparators 171 and 172 are operative. Generally stated, these comparators in combination with registers 176 and 177, and a pair of sector count registers 182 and 183, provide for detecting and memorizing the high and low points of each bezel facet image of which an imaginary image center can be ascertained and used as a measured angle parameter of the associated bezel facet. As described herein, the same technique or system is employed for measuring the angles of the various pavilion facets. It would be appreciated that the disclosed system is but one possible technique for making these facet or cuts angle measurements.

To measure each bezel angle each of the bezel facets is rotated through full revolution so as to cause its associated image to scan across the various photocells of each of the 10 bezel sensor sectors. To initiate this sequence, a BZ mode signal is issued by counter 122 causing analog sector select network 161 to sequentially select sectors 1 through 10 in synchronism with the movement of the index bezel image across sensor 91. As this occurs, register 176 and 177 store the order of the photocell numbers 1 through 12 corresponding to the low and high point of the scan image for the index bezel facet. Along with this storage of information sector registers 182 and 183 store the sector location at which the four bit counts registers 176 and 177 occur.

The count information carried by these various registers may now be used to determine a center of image corresponding to the associated bezel cut which in turn may be correlated to particular angle for that facet.

The center image is calculated automatically in the following manner. The coarse angular information is carried by registers 176 and 177, representing respectively the low and high image points on the mask of sensor 91. This low and high count information is subtracted digitally by a digital subtractor 184 and thereupon converted to an analog signal by a digital to analog converter 185 and divided in half by a divide by two operational amplifier circuit 186 whereupon the result of that calculation is added to an analog signal representing the low photocell information as provided by the output of a digital to analog converter 187 connected to register 176. This summation is performed by a summing amplifier 188. The output of summing amplifier 188 carries an analog signal representing roughly the center point of the bezel cut image impinging on the mask of sensor 91 as measured by the window or photocell positions 1 through 12 within the various sectors. As stated earlier, the separation between each window 39 within a given bezel sector represents 5 degrees variation or step of the bezel cut. Thus by subtracting the photocell associated with the high and low points of the image, and dividing that difference by 1/2 as performed by divide by two amplifier 186, and adding this result to the signal from digital to analog converter 187 representing the low point of the bezel image, the output of summing amplifier 188 results in a signal which can be related roughly to a point on the mask of bezel sensor 91. For the present embodiment this is achieved as follows. A geometrical center of the mask 138 of bezel sensor 91 corresponds to the center point of a bezel image associated with a middle size reference stone of predetermined dimensions. Thus for a stone having a predetermined reference size, light images from the bezel facets thereof, if perfectly cut, will scan across the geometrical center of the bezel sensor mask and the output from summing amplifier 188 will carry an analog signal representing the geometrical center of the mask 138.

For gemstones of a size greater or lesser than the reference stone, a compensating factor must be added to the angle signal from amplifier 188, which is here provided by a function generator 190 generating a compensating function f(GD) responsive to the previously measured girdle diameter GD signal and where the output therefrom is summed with the output of summing amplifier 188 and additional summing amplifier 189. The output of summing amplifier 189 thus represents the center point of the bezel image for the measured stone.

Moreover, this output signal may be adjusted such that if the stone is perfectly cut the output from summing amplifier 189 will be zero. If the bezel angle is greater than the ideal cut, then a positive signal is generated having a magnitude representing the amount of angular deviation. Whereas, a negative signal may represent an angle less than ideal with the magnitude thereof again representing the amount of deviation. However, as the analog signal from summing amplifier 189 is responsive only to the course angular measurements provided by the 1 through 12 photocell position information, it is necessary to add or sum to this coarse angular measurement signal, the finer angular information pursuant to the sector count location of each image.

The sector information is generated by

subtracting the sector counts carried by sector registers 182 and 183 in a digital subtractor 196, after determining which of the two counts is larger by means of a comparator 197, and converting the digital difference signal at the output of subtractor 196 into an analog signal by means of a digital to analog converter 198. The output of converter 198 thus represents in analog from the difference between the sector in which the highest point of the bezel image is located relative to the sector in which the lowest point of a particular image was sensed. To locate the center point between the high and low image sectors, it is necessary to divide the output of converter 198 by 1/2, here performed by a divide by two operational amplifier 199 and to add the result of such division to the analog signal representing the angle of the lowest order sector where this is provided by a digital to analog converter 200 and the summing is provided by summing amplifier 205.

The output of summing amplifier 205 represents the deviation of the bezel image in 1/2 degree steps and this signal is added to the coarser signal measurement provided by the output of summing amplifier 189 by means of a resultant summing amplifier 195, the output of which is an analog signal of plus or minus polarity representing the plus or minus angular deviation of the facet cut relative to an ideal cut angle.

Signal information identifying the particular bezel facet associated with each output from summing amplifier 195 is available from the sector count circuit 121 referred to the index bezel facet.

Pavilion Angle Measurement

The pavilion angle cut is measured by projecting a beam of light or other radiation 191 as shown in Fig. 13 so as to impinge upon an upper portion of each pavilion cut as the stone is rotated and is reflected from there toward pavilion sensor assembly 92. In this instance beam 191 is generated by a .9 micron laser pavilion light source 84 which may employ a laser diode of the type mentioned for bezel light source 83. The source 84 is mounted above platform 39 and is outwardly radially spaced from the center line of the stone and angled inwardly so as to direct beam 191 downwardly and sloping toward the axis of the assembly by an angle of approximately 6.5 degrees. For an ideally cut stone, the pavilion facets will slope at 41 degrees away from the plane of the table facet in this instance corresponding to the horizontal plane. By this arrangement, and for stones having a pavilion cut at or close to 41 degrees, all sizes of stones within a selected range can be measured. As the pavilion cuts are very slender adjacent the girdle, it has been found preferable to focus beam 191 so that it forms a localized light spot impingement upon the upper 25 percent of the gem as thus illustrated in Fig. 14 where the distance "a" represents the dimension between the culet facet and the upper points of the lower girdle facets. It is in this region that the beam 191 is directed to impinge upon the stone.

The construction of pavilion sensor assembly 92 is similar to bezel assembly 91 in that a mask 192, best shown in Fig. 17 is provided having a plurality of windows 193 arranged in groups of 12 along radial segments symmetrical with the axis of the stone. Mask 192 is of a generally rectangular shape having a slight circumferential wrap about the stone's axis and being arranged to slope upwardly and away from the axis at the 6.5 degrees at which beam 191 slopes toward the axis. In other words the face of mask 192 is parallel with beam 191 such that the distance over which the light is reflected from any size stone is constant.

The photoelectric cells or sensors 194 are disposed behind the windows and are mounted in closely spaced juxtaposition with a separate cell for each window in the manner of sensors 141 of bezel sensor assembly 91. As the reflected image from beam 191 scan across the face of mask 192, light passed by the various windows 193 trigger the associated sensors 194 thus representing the position of the image scan in terms of electrical signals which may be processed so as to develop an angle measurement for each pavilion facet in manner similar to the measurement of the bezel facets. The pavilion measurements are performed following the bezel angle measurements and while the stone is still rotating.

The pavilion cut angles are measured and stored in the same manner as the bezel facet measurements. For this purpose sequence select counter 122, issues a PV mode signal following the bezel measurement which precipitates analogous operations in processor 151 to those described above for the bezel measurement made. Also, this turns off bezel light source 83 and actuates pavilion light source 84.

However, for the PV mode, it is necessary in the disclosed embodiment to divide the pavilion sensor in to angular sectors smaller than the bezel sectors because of the geometry of the mask 192 of pavilion sensor 92. For this purpose processor 151 includes a pavilion divider 225 and a switching network 226 which serve to provide a higher frequency clock train to half sector clock 156 so as to generate smaller sectors during the pavilion mode. Nevertheless, the the various sectors 1 through 10 of the bezel angle sensor assembly 91.

remaining operations for the pavilion measurements are the same as for the bezel measurements. Networks 161 and 162 are operative to select the pavilion sensor photocells during this operating sequence by extending a PV mode signal to network 161 as shown.

The result of this operation is the development of pavilion angle signals at the output of summing amplifier 195, which signals are referenced to the index bezel facet by means of the sector count information available from circuit 121.

Color Measurement

The color measurement follows the pavilion out measurement and as stated above generally comprises a comparative light source means in which light sources of different frequencies are directed through the stone and a comparative photosensor means arranged to measure relative attenuation of the different light frequencies or wavelength. More particularly, the color of a diamond is to a large extent determined by the quantity of occluded nitrogen trapped in the body of the material during fomation of the diamond. It is known that certain frequencies or wavelengths of electromagnetic radiation are absorbed by nitrogen and it is this phenomena which permits the comparative color measurement of the present invention. Of the two light source means employed for the color measurement, a light source 86 is the one in this instance selected to have a wavelength or frequency which exhibits the greatest absorption by nitrogen inclusions within the stone. The other light source means is in this instance provided by the bezel laser source 83 in which the wavelength or frequency emitted thereby is generally unaffected and thus unattenuated by the nitrogen substance. For this purpose, laser light source 86 may be provided by a 7.8 micron wavelength laser light source while light source 83 may be provided by a .9 micron wavelength source as in the case of its function as a bezel light source.

With reference to Fig. 15, source 86 is disposed within a housing 201 having a light passage 202 for directing a beam of radiation 203 through a beam chopper 204 so as to reflect off a 45° angled beam splitter 206 having a mirrored surface for deflecting beam 203 upwardly through platform 39 and into the table facet of the diamond. Chopper 204 provides an intermittent beam of the 7.8 micron radiation. During the intervals in which beam 203 is blocked by chopper 204, the .9 micron laser source 83 is pulsed so as to cause a radiation beam 129, the same radiation beam employed for the bezel angle measurement as shown in Fig. 11, where this beam passes upwardly through a lower beam splitter, a lens assembly and through the upper beam splitter 206 so as to enter the table facet at the same point as radiation beam 203 although at times 180° phase opposed thereto. At the time these beams enter the table facet, they are diverging as shown by dotted lines 207. Some of this divergent light emanates from the culet facet 72 of the stone and travels upwardly therefrom so as to impinge upon a comparative photoelectric sensor assembly 93 carried adjacent the axial end 116 of height probe 114 as shown. Sensor assembly 93 may be comprised of first and second photoelectric sensors arranged in tandem or back-to-back with a first sensor 208 responsive primarily to the 7.8 micron radiation from source 86 and transmissive of the .9 micron radiation from source 83 and with a second sensor 209 primarily responsive to .9 micron radiation and being disposed behind sensor 208. The arrangement of these sensors is also shown in Fig. 7. Electrical leads from the sensors extend upwardly through a hollow portion of the probe 114.

Thus sources 86 and 83 are alternately impingent upon the table facet of the stone and the output radiation from the culet facet 72 thereof is detected and compared by measuring the relative outputs of sensors 208 and 209. The greater the attenuation of the 7.8 micron radiation from source 86 relative to the attenuation of the 9 micron radiation from source 83, the greater the nitrogen inclusions in the stone and the greater the yellowness or off-color of the gem.

With reference to Fig. 22, a color processor 210 is illustrated in which alternation of the impingent radiation on the stone is provided in the following manner. Timing information from the AC synchronous motor current for motor drive 82 is applied to an AC derived clock generator 211, which is here shown as a separate component although it may in the alternative be provided by an AC derived clock generator 152 of sector counter circuit 121 as shown in Fig. 21. The 90 clocks per sector of rotation from generator 111 are fed to a clock divider 212, here providing a clock output divided by 24 which is fed to a clocking input of a flip-flop 213. The switching operation of flip-flop 213 in response to the clock output of divider 212 serves to enable .9 micron laser 83 to be activated during the proper interval and provides for alternately enabling putput signals from sensors 208 and 209 synchronously with their associated radiation sources. The 7.8 micron source 86 is powered by a power supply 214 enabled through a gate 216 in response to the color (CO) mode signal from sequence select

counter 122. Chopper 204 is similarly enabled by an output of gate 216 and is driven synchronously and phase opposed to laser source 83 by a synchronous motor operating off the same AC motor current driving generator 211. In this manner, an intermittent beam of radiation from source 86 is synchronised and adjusted so as to be 180° out of phase with the activation of laser source 83. Flip-flop 213 with Q output thereof high and an enabling signal from the color (CO) mode output of sequence select counter 122 causes a gate 217 to receive the clock signals from generator 211 and pulse laser source 83 at the clock rate by means of a laser pulse generator 218. Thus, the radiation from laser source 83 during its active mode is a pulsed beam, typically at a repetition rate of 1 Kilohertz. Gates 219 and 221 having inputs connected to the Q and $\overline{Q}$ outputs of flip-flop 213 respectively provide the alternate enabling of sensors 208 and 209 in synchronization with sources 86 and 83 respectively. Sample and hold amplifiers 222 and 223 receive the intermittent outputs from sensors 208 and 209 respectively and develop slowly varying DC voltages representing the intensity or output strength from the sensors in response to the intensity of radiation received thereby. A difference amplifier 224 having its inputs connected to amplifiers 222 and 223 develops a difference signal, which is an analog voltage signal identified as CO at the output of amplifier 224. The larger the difference in the outputs of sensors 208 and 209 the greater the attenuation of the 7.8 micron radiation with respect to the .9 micron radiation and the greater the analog output signal CO representing the color measurement. Initially, the outputs from sensors 208 and 209 may be normalized or calibrated by energizing the color processor during the absence of a stone on platform 39. The various components may, at the time, be adjusted to provide an equal output level and thus a zero output for the color analog signal CO.

The analog signal CO representing color is extended to the terminal computer where it is processed for transmission to the data processing center. Within terminal computer 32, or at data processing center 30, a normalized color value may be achieved for the stone by dividing the magnitude of the color signal CO by the height of the stone previously measured. This provides a measurement of the comparative or relative attenuation of the 7.8 micron beam for a unit length of diamond substance. Otherwise, the color measurement generated by color processor 210 will vary with the size of the stone.

For source 83, it has been found that a commercially available miniature diode laser may be employed to provide the .9 micron radiation. For source 86, the 7.8 micron wavelength is in the middle infrared radiation band and thus a heat source with a suitable filter may be utilized for this component. In the alternative, and as disclosed herein, source 86 may be provided by a laser having a 7.8 micron wavelength emission.

For the present embodiment, the color measurement is performed during one full revolution of the stone as determined by sequence select counter 122. However, the comparative light attenuation measurement for the color parameter may be obtained over a shorter period of time, and with or without rotation of the stone if desired. The full 360° stone rotation insures that the radiation beams are not affected by local minute aberrations on the stone which may influence the measurement at only one angular condition.

Clarity Measurement

The stone's clarity is measured following the color mode and for this purpose sequence select counter 122 of the terminal computer 32 issues a CL mode signal at the proper time and the signal is communicated to a clarity processor 241 of Fig. 23 and to and for turning on a clarity light source 87. Source 87 is shown in Fig. 18 mounted above platform 39 and arranged to direct a divergent beam 242 of light which impinges upon the pavilion and lower girdle facets of the stone as shown in Fig. 18. This causes light to enter the stone such that if it intercepts a flaw or inclusion it will be scattered or in some instances absorbed depending upon the nature of the inclusion. Clarity sensor assembly 96 includes a photoelectric cell 243 disposed within a light passage 244 so as to receive light originating from source 87 and dispersed downwardly through light passages 246 and 247 and deflected at generally right angles toward photoelectric cell 243 by a beam splitter 248. The clarity of the stone is determined by sensing this scattered or absorbed light impingent on the photocell while scanning the interior of the stone body. Such scanning is here achieved by a variable focus assembly 251 having a lens system mounted within the light passage 246 as shown and a variable radial drive assembly 252 effecting a controlled displacement of a lower moveable housing 253 which contains passage 247, beam splitter 248 and a photocell 243. With these variable assemblies scattered light from different internal regions of the stone may be focused on the photosensor. Variations in the electrical output of cell 243 serves as a measure of the stone's clarity in terms of the

absence or existence of inclusions or other flaws. A black background 254 may be provided above the stone so as to enhance the contrast and thus resolution of the light measurement by photocell 243.

Clarity scanning is performed while the stone is still rotating on platform 39. Variable focus assembly 251 serves to define the depth d, of the localized internal region of the stone observed by cell 243. This is illustrated in Fig. 19 as a scanning depth d, where the depth is coincidental with the height dimension between tha table and culet facets. Variable radial drive assembly 252 provides an incremental radial displacement of lower housing 253 relative to housing 201 so as to cause lens assembly 251 to focus at a region which is radially displaced from the center axis of the stone. Thus as the displacement r, is increased, photocell 243 "looks at" internal stone regions which are radially removed from the central axis of the stone. This radial displacement or increment r, is shown in Fig. 19. As the stone is continuously rotating during the scanning operations, it will be observed that the entire interior body of the stone may be selectively read by cell 243.

The output of the photosensor is fed to a storage component of terminal computer 32 along with positional information representing the depth of scan d, the radial displacement r, and the angular rotational position of the stone as represented by previously generated sector count information from sector counter circuit 121 shown in Figs. 20 and 21. Thus with reference to Fig. 23, clarity processor 241 is here provided by half sector counter 156 of sector counter circuit 121, a radial increment (RI) counter 261 for accumulating count information of the radial displacement r, and a vertical increment (VI) counter 262 for storing the position of adjustable focus assembly 251 which in turn represents the depth d, of the scan. During operation, a clarity mode enabling signal is received from sequence select counter 122 by a clarity processor gate 263 as shown in Fig. 23 enabling an output clock pulse every half sector of rotation to pass to and for clocking counter 261. Simultaneously, this half sector clock pulse is extended to a radial increment (RI) stepper motor 264 serving as a means for driving radial drive assembly 252. Radial drive assembly 252 thus begins stepping housing 253 away from the center position in which light passages 246 and 247 are aligned and counter 261 counts the number of such steps occurring and this process continues until counter 261 reaches a count corresponding to the outer radius of the stone's girdle, as provided by the girdle diameter measurement divided by two in a divider 266. Thereupon, a comparator 267 detects that the output of a digital to analog converter (DAC) 268 representing the RI count in analog form equals one half the girdle diameter provided by divider 262 and thereupon causes a logic signal to be issued at the output of an OR gate 269 triggering a flip-flop 271 from one state to another of its stable states. This causes the direction of RI counter 261 to reverse by means of a connecting line 272. Simultaneously, the output of OR gate 269 issues a logic signal to VI counter 262 and to a VI stepper motor 273 here serving as a means for driving adjustable focus assembly 251. Also simultaneously with the switching of flip-flop 271, the connection line 272 is extended to RI stepper motor 264 to cause a reversal in the radial stepping direction so as to scan inwardly but at a different focus depth. Upon reaching the stone's center line the radial scan is reversed by a "O" output of counter 261 connected to OR gate 269.

A digital to analog converter (DAC) 274 provides an output connected to a comparator 276 which compares the count level on counter 262 with the previously measured analog signal, height Ht and when the scan has proceeded to a depth level equal to the stone's height then the output of comparator 276 issues a signal which may be connected to the sequence select counter 222 informing it that the clarity scan has been completed.

The analog outputs from converters 268 and 274 are also communicated to a memory portion of terminal computer 32 for storage along with the rotational position developed by a digital to analog converter 277 operating off of half sector counter 256. Together the FI (r), VI (d) and half sector count (HSC) define the internal position of the stone at which a particular output from clarity sensor assembly 96 occurred. The clarity sensor analog signal (CLS) is likewise fed to terminal computer 32.

The output of clarity sensor assembly 96 may be either a discrete yes or no signal, representing the existence of absence of a flow of a certain threshold magnitude, fixed by adjusting the sensitivity of photosensor 243 and the magnitude of light 87, or the output of cell 243 may be a continuously variable analog signal. In the latter case, the analog signal may show high and low values representing the light scattering and absorption respectively by stone inclusions. Thus a perfect stone may show little if any variation in the output of the photo-cell for a complete scan whereas a less clear stone will show variations in the analog output. Whether a discrete logic output is employed or a variable analog output, the location of the flaw is in both cases identified by the

radial and vertical increment signals representing r and d and the rotational position represented by the output of the half sector counter.

Terminal Computer

As previously indicated, terminal computer 32 as shown in Fig. 20 serves to correlate all the various measurement functions of the present invention and to collect the data therefrom for transmission to data processing center 30. For this purpose and with reference to Fig. 20, an analog switching circuit 281 operated by an address counter 282 from input-output logic and address clock circuit 283 provides for receiving various measurement signals and for connecting them in a proper sequence to an analog to digital converter (DAC) 284. Converter 284 is provided with parallel outputs connected to a shift register 286 which provides for serially storing the digitized data information developed by converter 284 into a data store 287. Synchronous clocking of shift register 286 and data store 287 is provided by address counter 288 as indicated operating from address clock signals from circuit 283. The measurement data thus memorized in store 287 is thus made available for transmission to center 30 after being suitably processed by a modem 289. Additionally, the data in store 287 may be printed by printer 36 and/or displayed by CRT display 38.

Since numerous changes can be made in the above described exemplary embodiment of the invention and other embodiments can be realized without departing from the scope of the invention, it is intended that the foregoing descriptive material and accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

WHAT WE CLAIM IS:—

1. Gemstone measuring, registering and identifying apparatus, comprising a data processing centre including means for storing received electrical signals, for comparing received signals with stored signals and for providing an indication of a match resulting from said comparison, together with a plurality of terminal means each including measurement means arranged to develop electrical signals representing the same set of predetermined parameters of a gemstone and means arranged to transmit said electrical signals from said terminal means to said data processing centre.

2. Apparatus in accordance with claim 1 wherein each said terminal means includes measurement means arranged to develop electrical signals representing cut angle parameters of the gemstone.

3. Apparatus in accordance with claim 2 wherein said terminal means includes bezel cut angle measurement means arranged to develop electrical signals representing bezel cut angle parameters of such a gemstone.

4. Apparatus in accordance with claim 2 or claim 3 wherein said terminal means includes pavilion cut angle measurement means arranged to develop electrical signals representing pavilion cut angle parameters of such a gemstone.

5. Apparatus in accordance with any one or claims 1—4 wherein each said terminal means includes measurement means arranged to develop electrical signals representing a weight parameter of the gemstone.

6. Apparatus in accordance with any one of claims 1—5 wherein each said terminal means includes measurement means arranged to develop electrical signals representing a color parameter of the gemstones.

7. Apparatus in accordance with any one of claims 1—6 wherein each said terminal means includes measurement means arranged to develop electrical signals representing flaw parameters of the gemstone.

8. Apparatus in accordance with any one of claims 1—7 wherein each said terminal means includes measurement means arranged to develop electrical signals representing a height parameter of the gemstone.

9. Apparatus in accordance with any one of claims 1—8 wherein each said terminal means includes measurement means arranged to develop electrical signals representing the girdle dimension of the gemstone.

10. Apparatus in accordance with any one of claims 1—9 wherein each said terminal means includes measurement means arranged to develop electrical signals representing a clarity parameter of the gemstone.

11. Apparatus in accordance with claim 1 wherein each said terminal means includes measurement means arranged to develop

electrical signals representing a weight parameter, a color parameter, and cut angle parameters of the gemstone.

12. Gemstone measuring, registering and identifying apparatus substantially as described with reference to the drawings.

A. A. THORNTON & CO.,
Chartered Patent Agents
Northumberland House,
303—306 High Holborn
London, W.C.1.

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1416568 COMPLETE SPECIFICATION

9 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1.

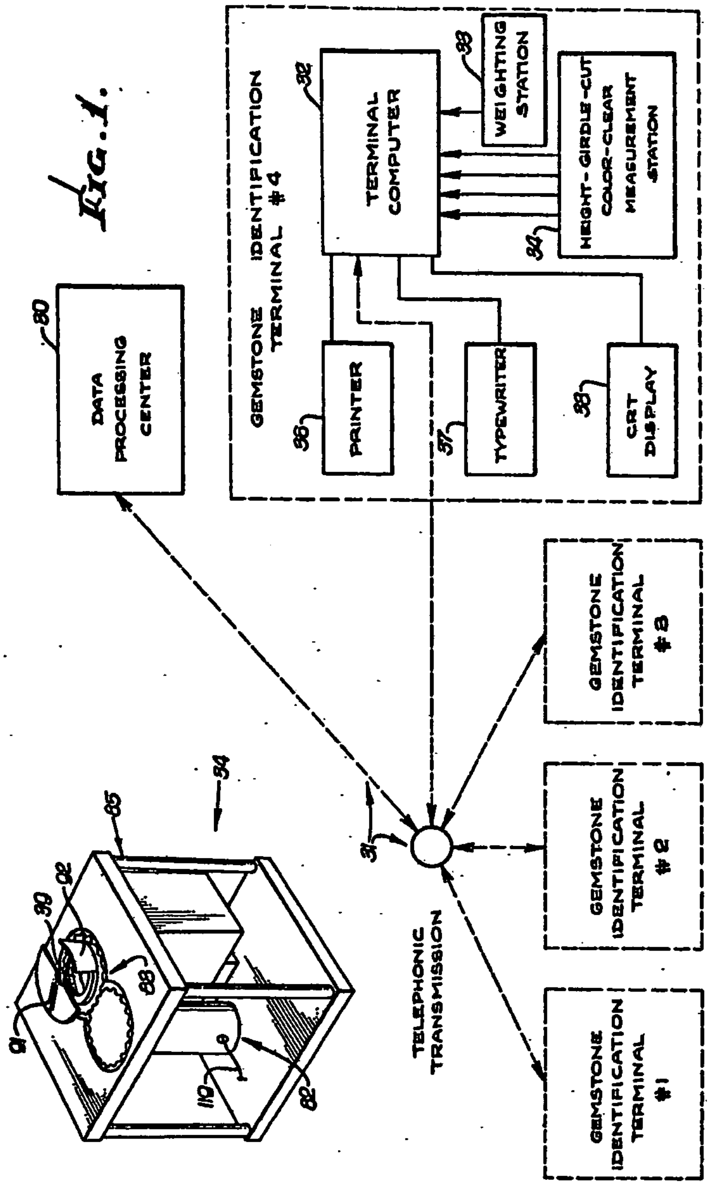

FIG. 2.

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Sheet 2

FIG. 3.

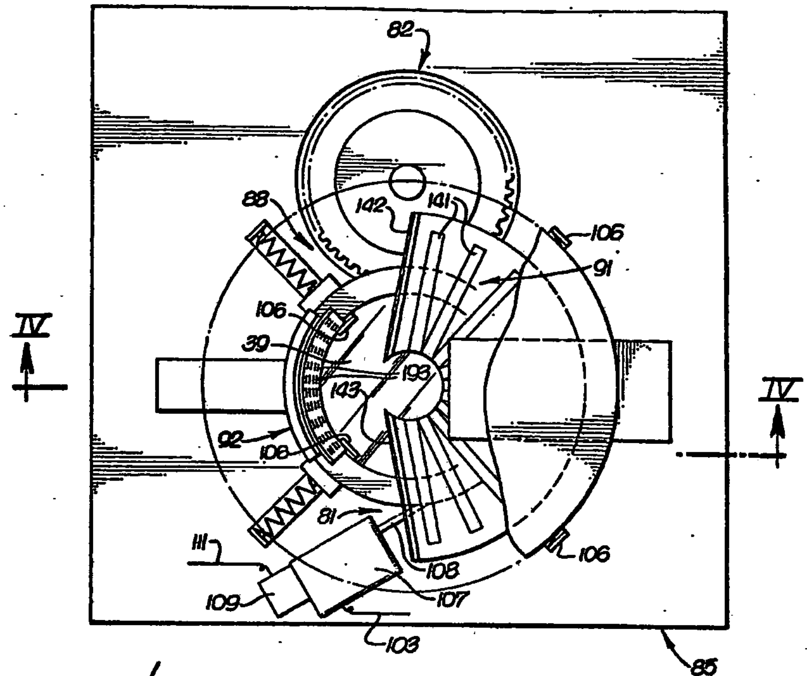


FIG. 4.

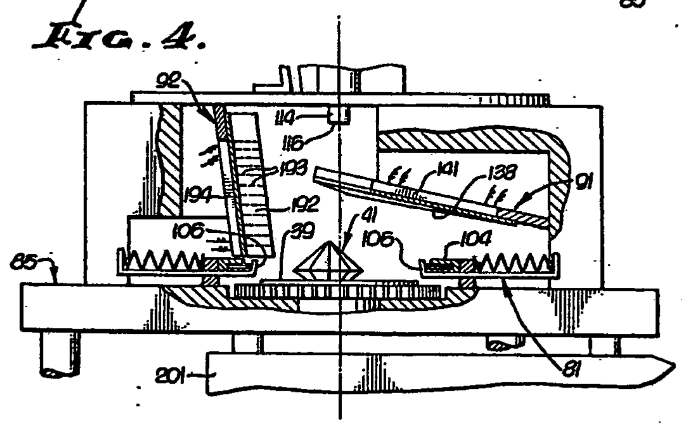


FIG. 5.

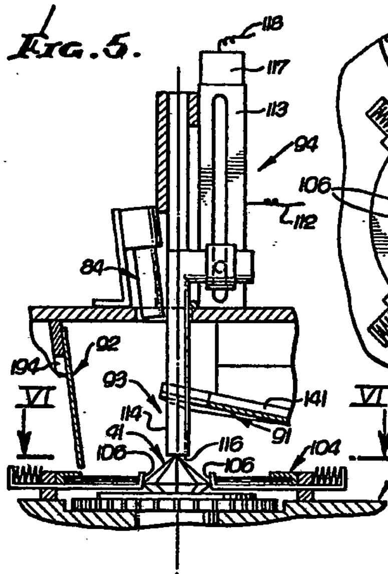


FIG. 6.

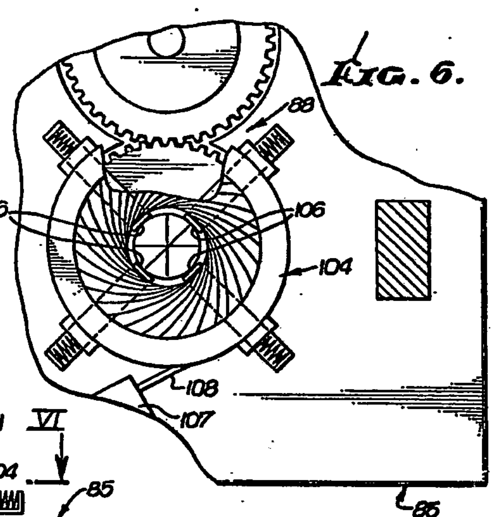


FIG. 7.

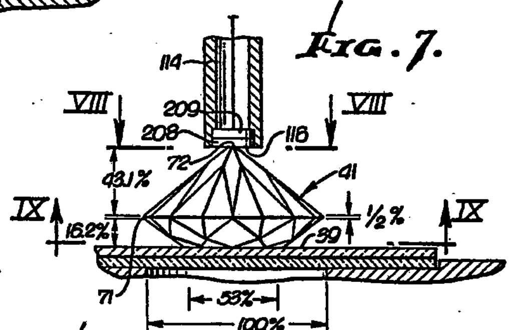


FIG. 10.

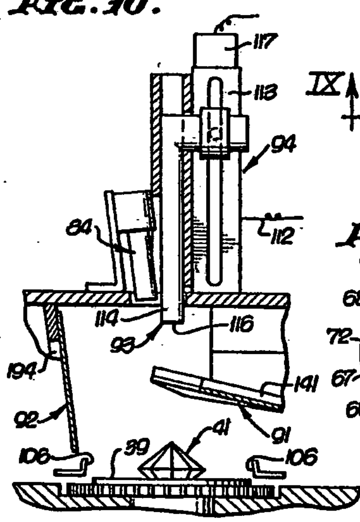


FIG. 8.

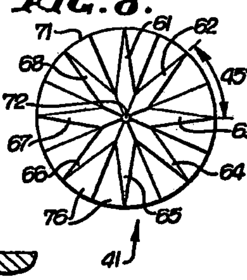
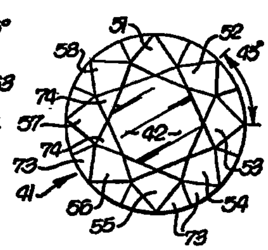


FIG. 9.



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Sheet 4

FIG. 11.

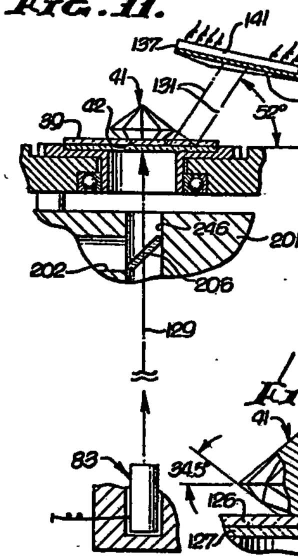


FIG. 19.

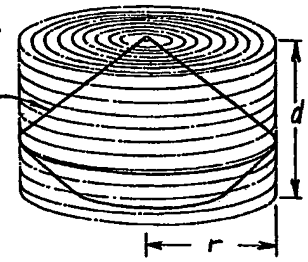


FIG. 18.

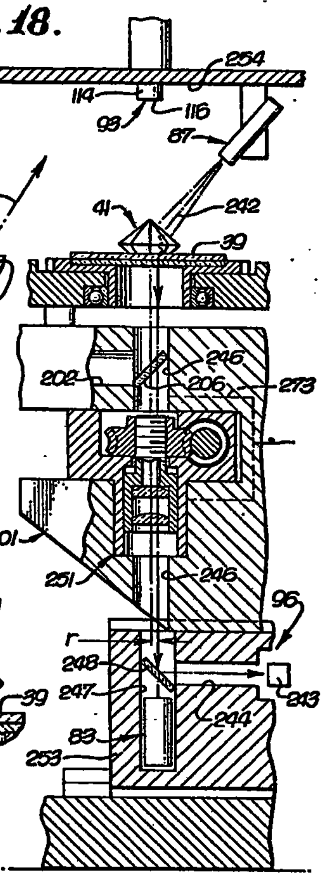


FIG. 12.

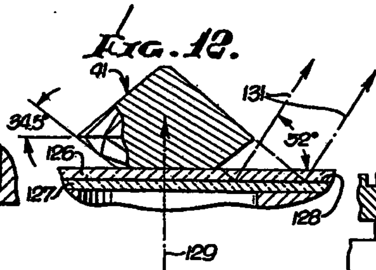


FIG. 13.

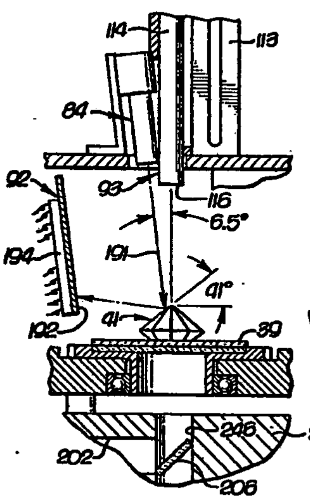
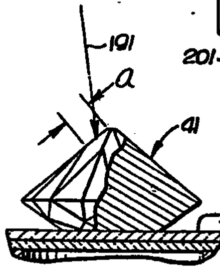


FIG. 14.



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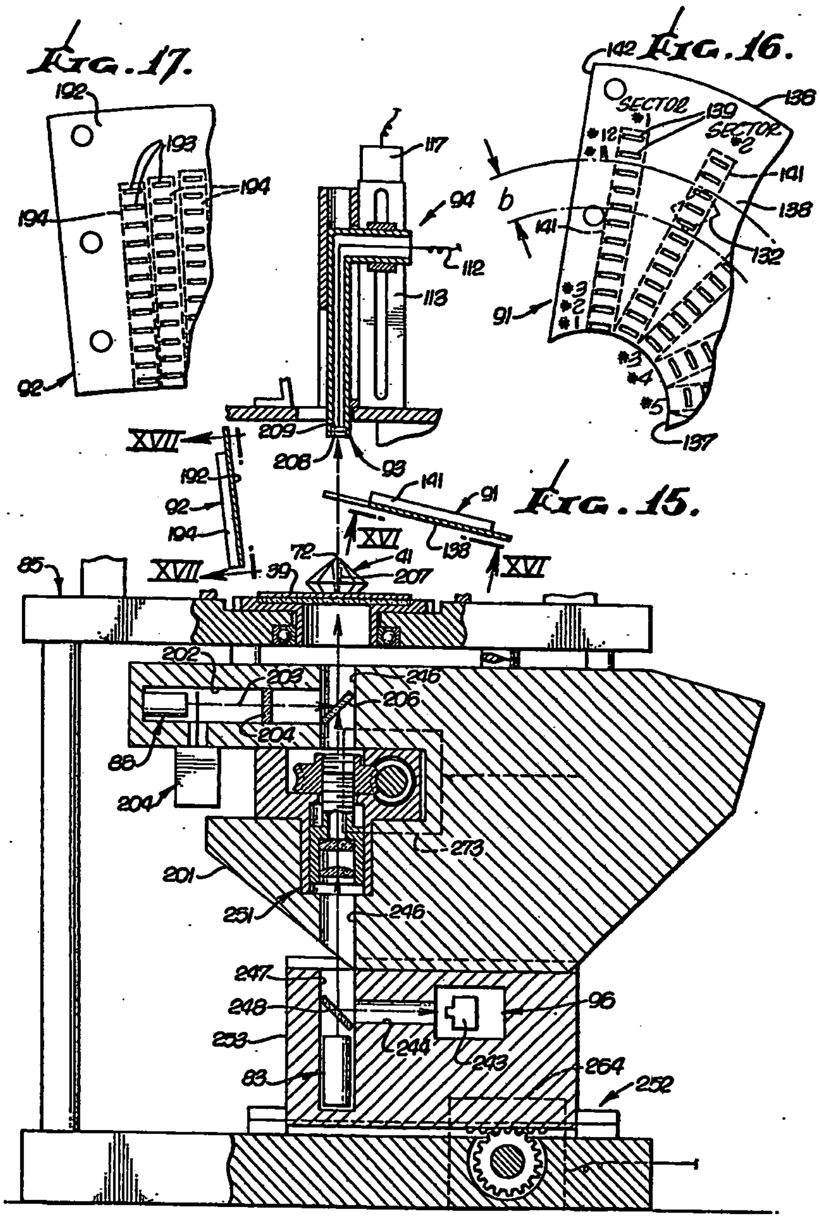
Sheet 5



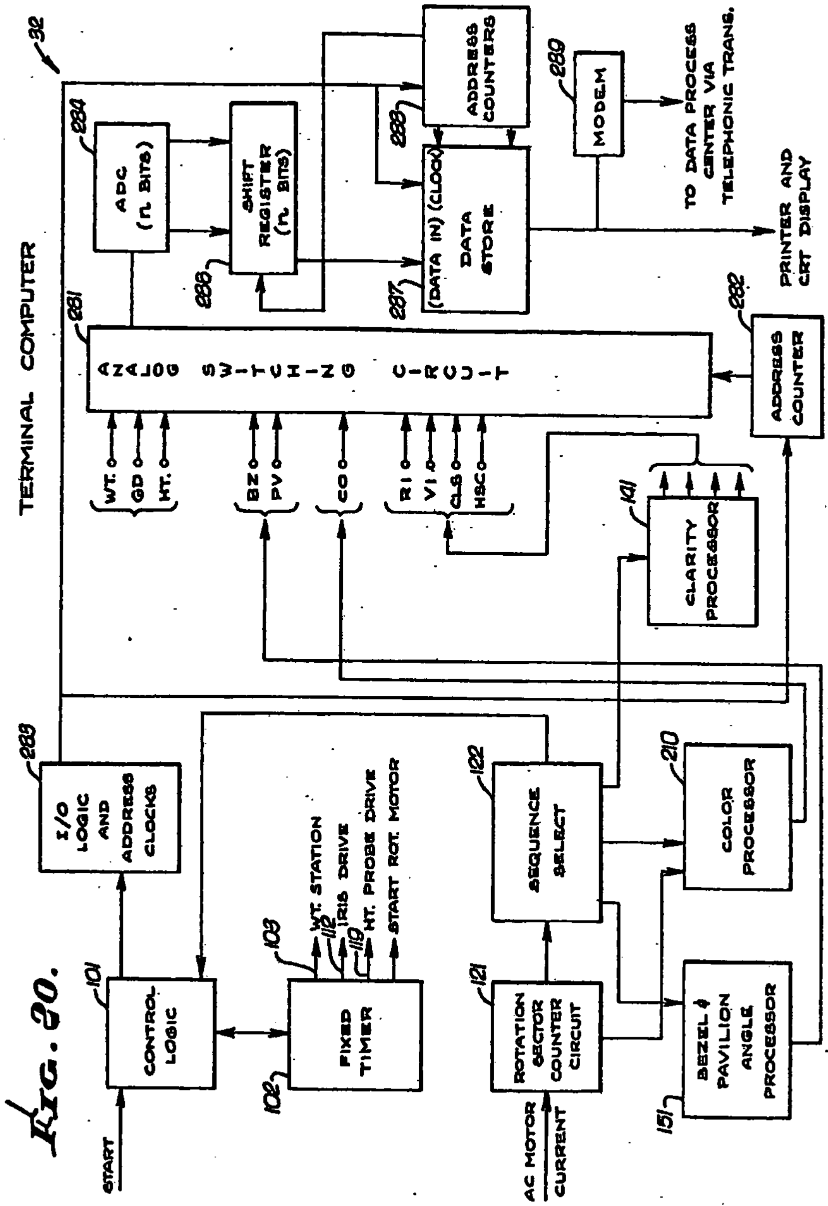

TERMINAL COMPUTER
32
ADC (n BITS)
284
SHIFT REGISTER (n BITS)
286
ADDRESS COUNTERS
288
(DATA IN) (CLOCK) DATA STORE
287
MODEM
289
TO DATA PROCESS CENTER VIA TELEPHONIC TRANS.
PRINTER AND CRT DISPLAY
ANALOG SWITCHING CIRCUIT
281
ADDRESS COUNTER
282
WT.
GD
HT.
BZ
PV
CO
RI
VI
CLS
HSC
CLARITY PROCESSOR
141
I/O LOGIC AND ADDRESS CLOCKS
283
CONTROL LOGIC
101
START
FIXED TIMER
102
103
WT. STATION
112
IRIS DRIVE
119
HT. PROBE DRIVE
START ROT. MOTOR
SEQUENCE SELECT
122
COLOR PROCESSOR
210
ROTATION SECTOR COUNTER CIRCUIT
121
AC MOTOR CURRENT
BEZEL & PAVILION ANGLE PROCESSOR
151

FIG. 20.

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Sheet 7

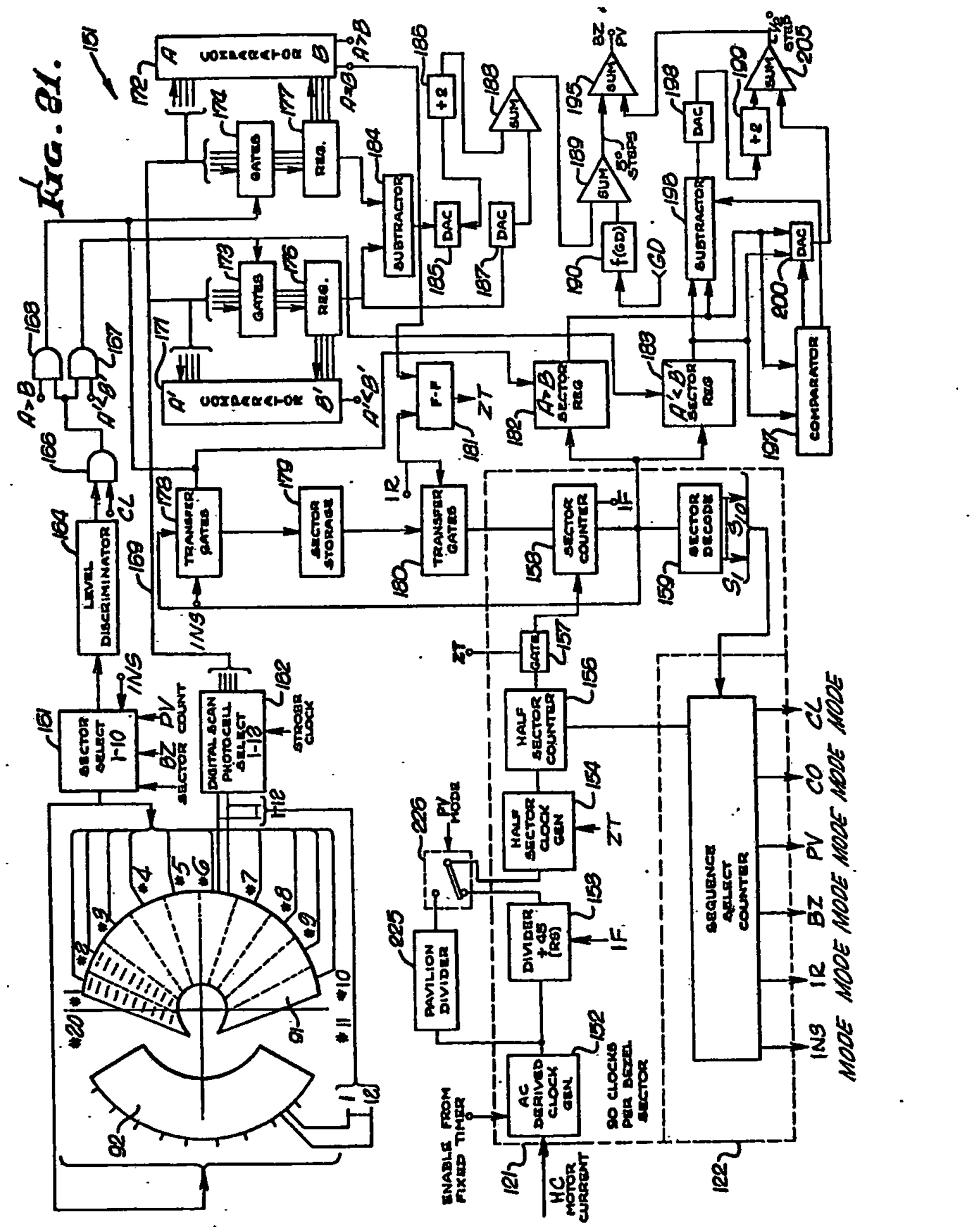

Fig. 21.

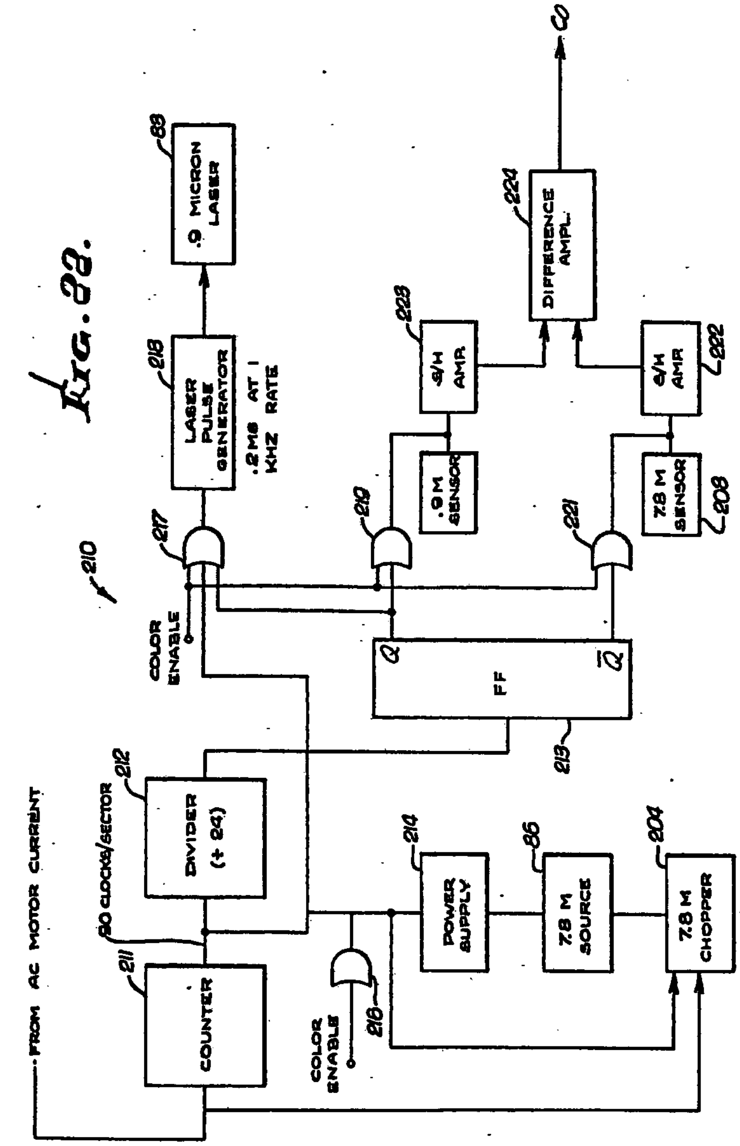
.9 MICRON LASER
88
LASER PULSE GENERATOR
218
.2 MS AT 1 KHZ RATE
217
219
221
210
COLOR ENABLE
.9 M SENSOR
7.8 M SENSOR
208
S/H AMP
223
S/H AMP
222
DIFFERENCE AMPL.
224
FF
Q
$\bar{Q}$
213
FROM AC MOTOR CURRENT
COUNTER
211
20 CLOCKS/SECTOR
DIVIDER (÷ 24)
212
COLOR ENABLE
216
POWER SUPPLY
214
7.8 M SOURCE
86
7.8 M CHOPPER
204

FIG. 22.

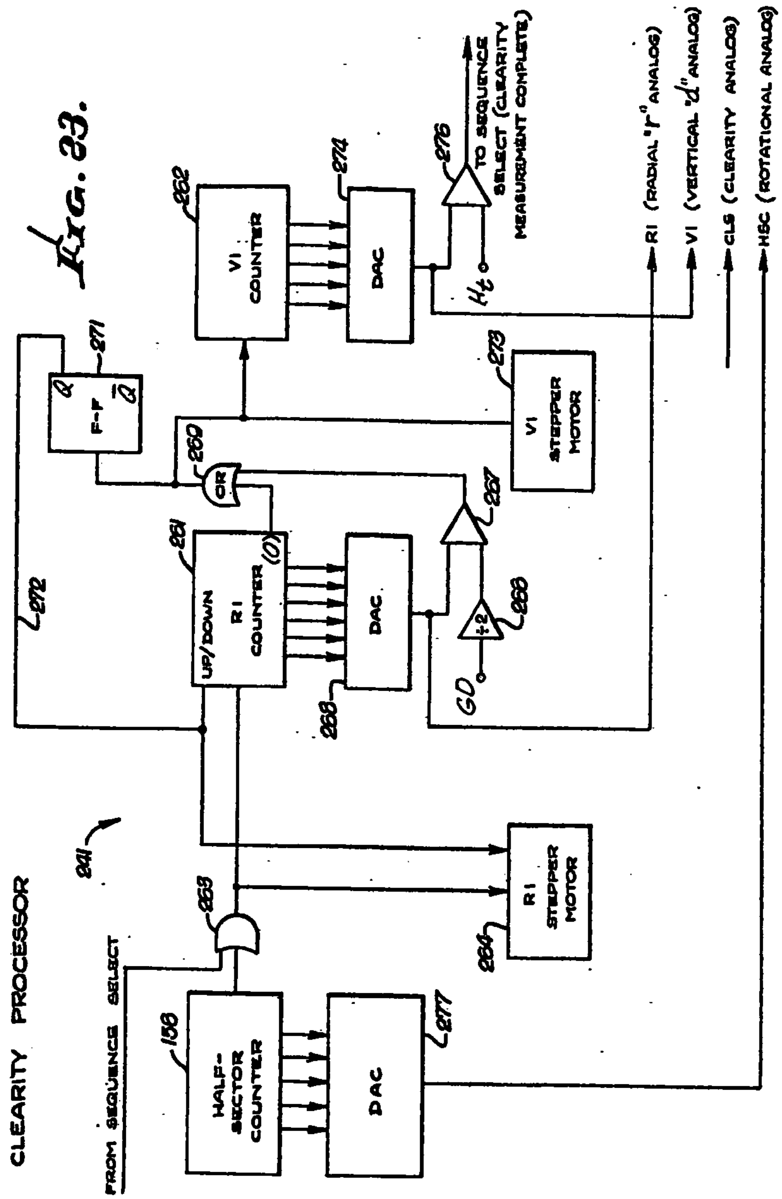
CLEARITY PROCESSOR
241
FROM SEQUENCE SELECT
HALF-SECTOR COUNTER
158
DAC
277
263
RI STEPPER MOTOR
264
UP/DOWN RI COUNTER
261
(0)
DAC
268
GD
÷2
266
267
OR
260
F-F
Q
$\bar{Q}$
271
272
VI COUNTER
262
DAC
274
276
H_t
TO SEQUENCE SELECT (CLEARITY MEASUREMENT COMPLETE)
VI STEPPER MOTOR
273
RI (RADIAL "r" ANALOG)
VI (VERTICAL "d" ANALOG)
CLS (CLEARITY ANALOG)
HSC (ROTATIONAL ANALOG)

FIG. 23.